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Repeated High-Precision Gravity & GPS at Dixie Valley

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Outline

- Project introduction
- Gravity/GPS data collection method
- Gravity changes, Jun 1999 - Jun 2000
- Elevation changes, Oct 1999 - Jun 2000
- Gravity changes, Oct 1999 - Jun 2000
- Gravity data analysis
  - (a) Dixie Valley, (b) The Geysers
- Conclusions

Project Introduction

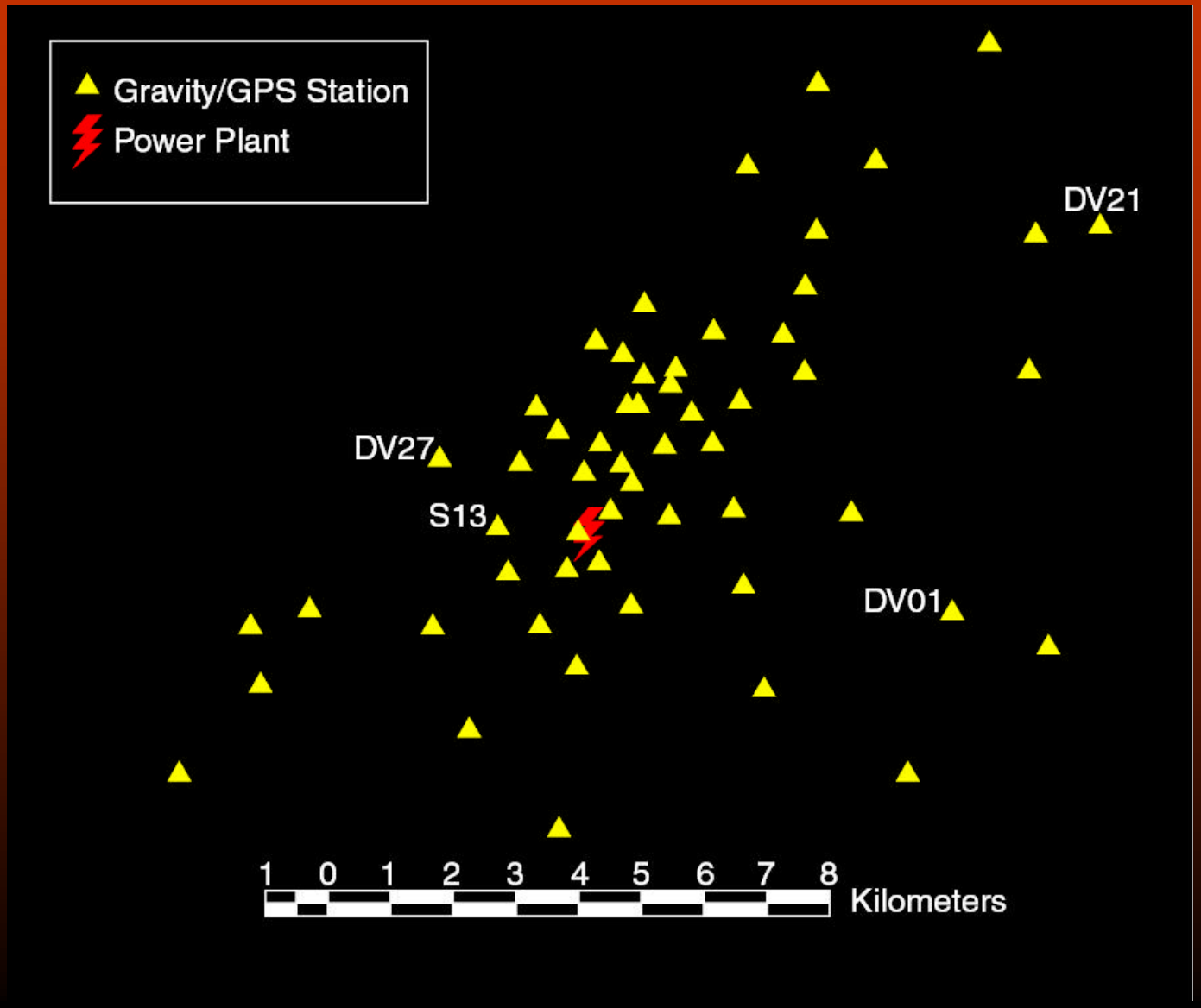
- Goals:
  - To improve the method and resolution of gravity & GPS measurements, including quantifying errors
  - To use repeated gravity & GPS measurements to image reservoir fluid changes
- Dixie Valley chosen as the initial geothermal field site.

Introduction (con't)

- Three campaigns at Dixie Valley:
  - June 1999
  - October 1999
  - June 2000

- Each campaign occupied 60 stations around the field with gravity & GPS measurements

Station Network



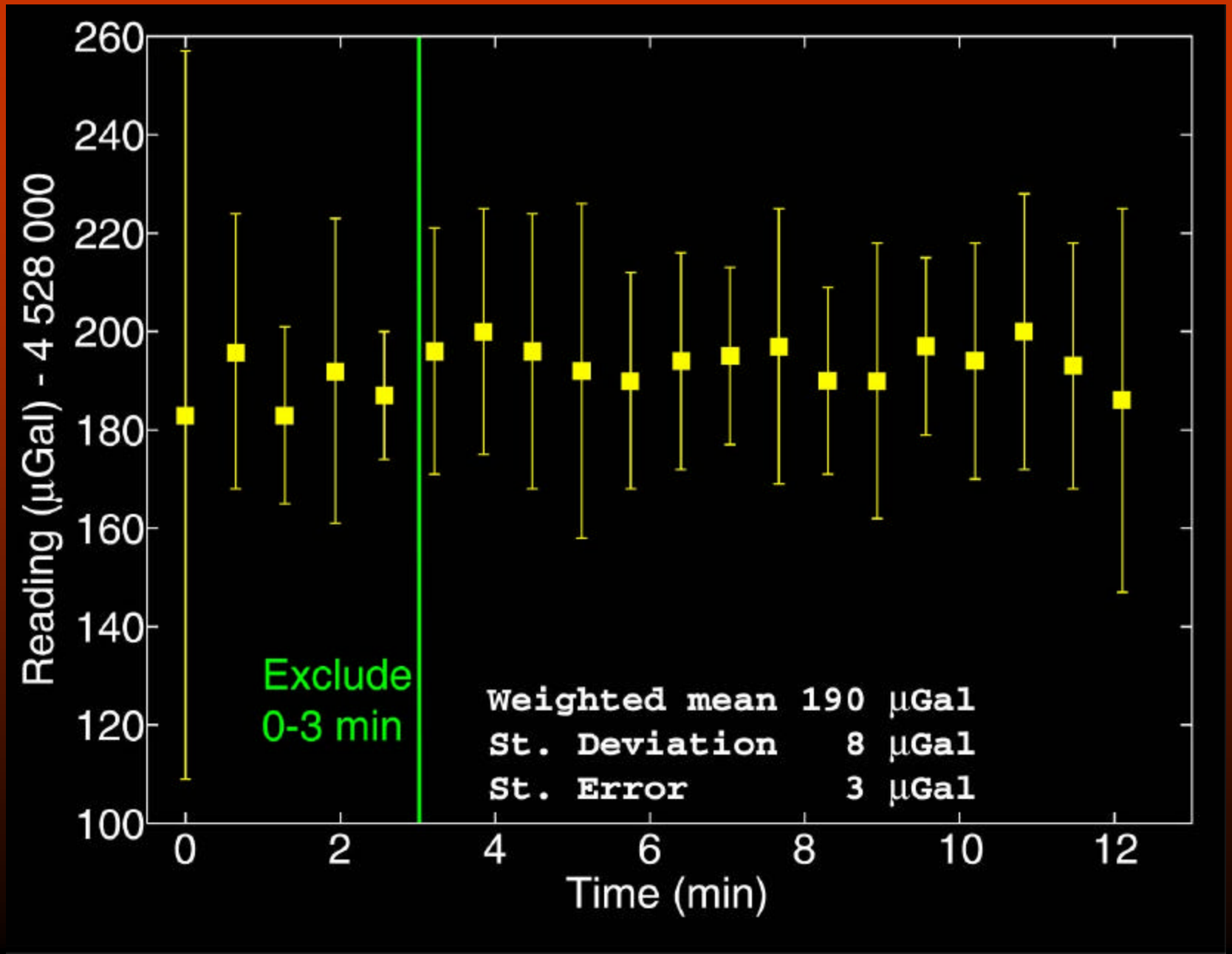
Gravity/GPS Field Method

- Gravimeter: Scintrex CG-3M (1 μGal prec.)
- GPS: Trimble 4000SSe, antennas have ground planes
- Stations are rebar driven into the ground, with a 12” cement pad for the gravimeter
- Gravity measurements taken on the pad, GPS measured from the top of the rebar

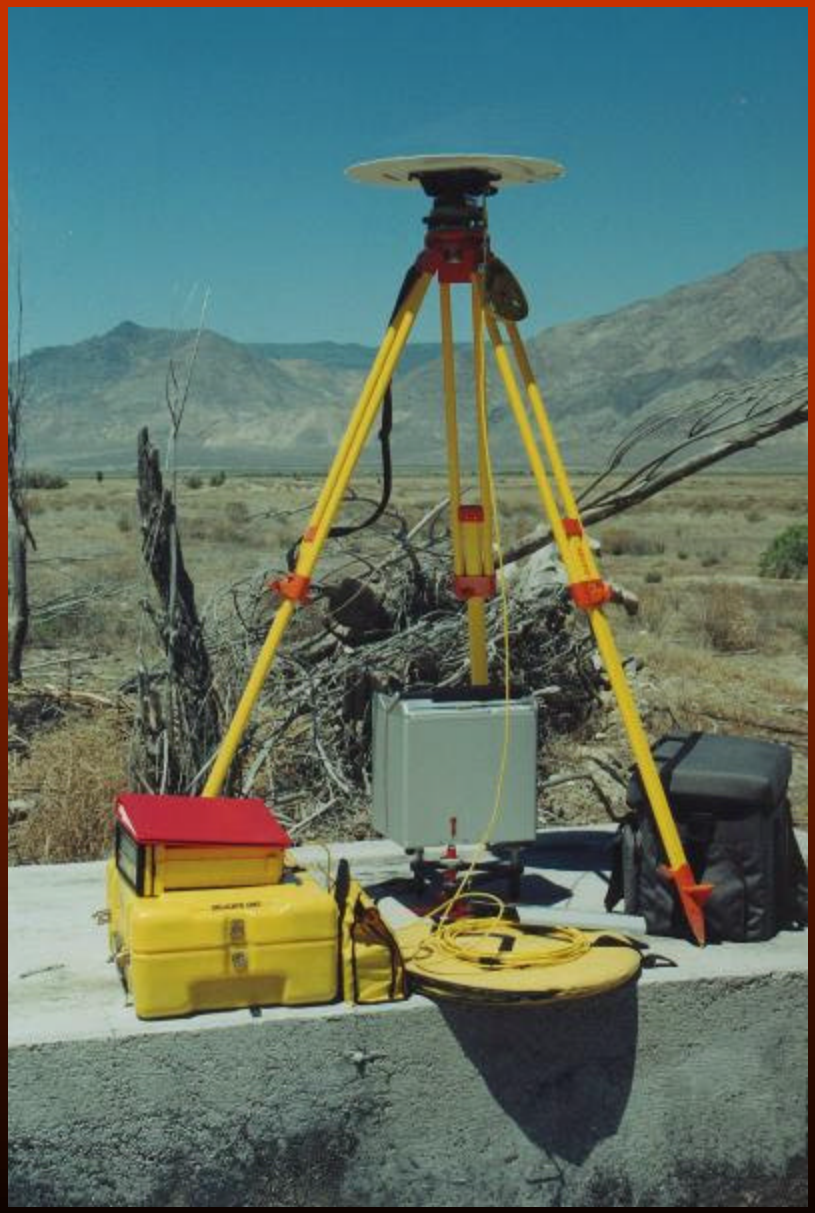
Gravity Measurements

- Gravity measurements taken at least twice on each station; local base occupied at least twice daily.
- Occupations store 15+ minutes of 30 sec averages; time series analyzed with Thiele extrapolation

Time Series Analysis



GPS Measurements



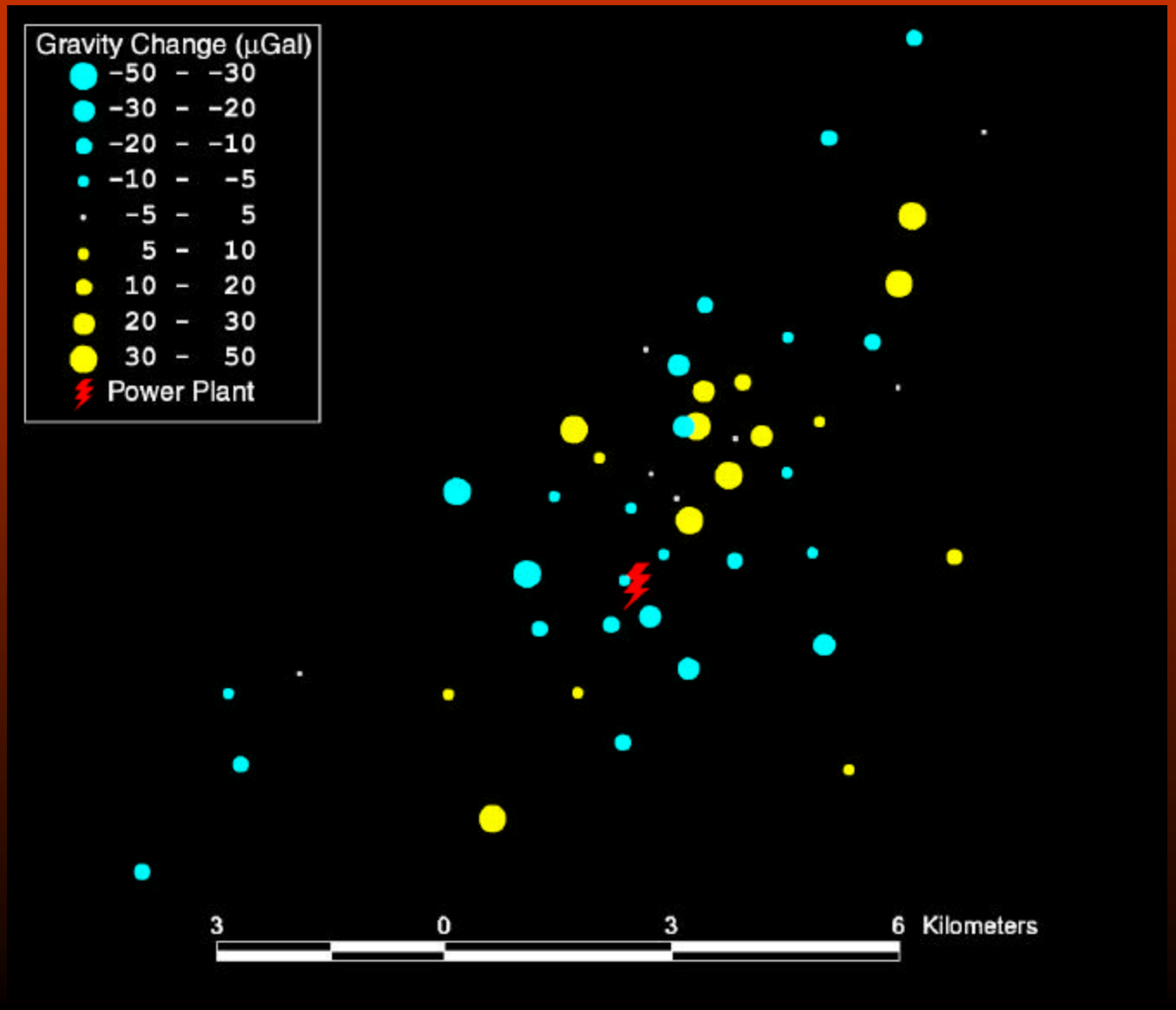
- GPS measurements taken for 30 minutes on each station.
- Each station occupied once.
- Data analyzed using Trimble Geomatics Office in post-processed differential mode

Gravity/GPS Errors

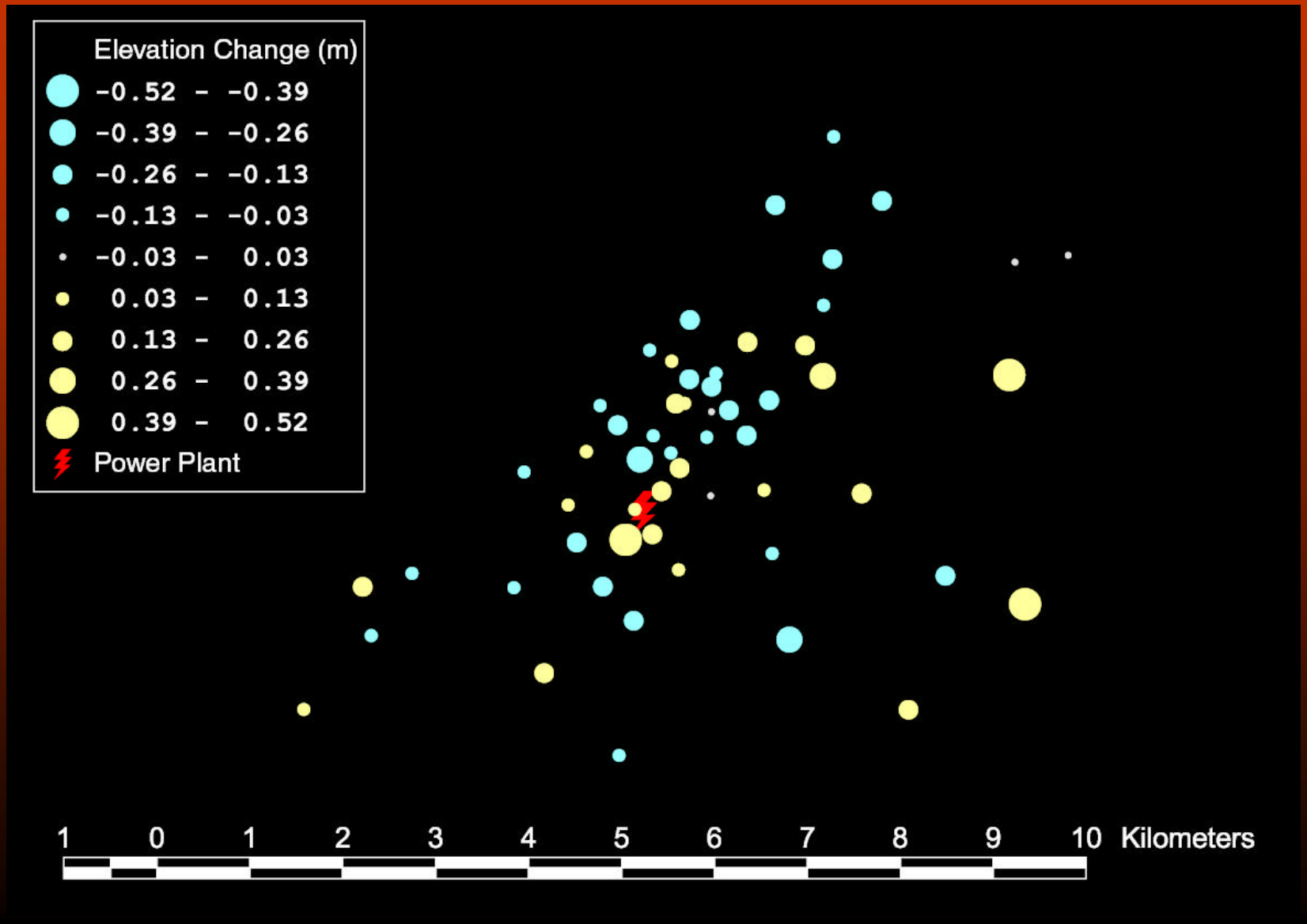
- GPS positioning error estimated as
  ±3 cm vertical
- Gravity measurement error estimated at
  ±5 μGal
- Free-air corrected gravity measurement error estimated at ±15 μGal

Uncorrected Gravity Change

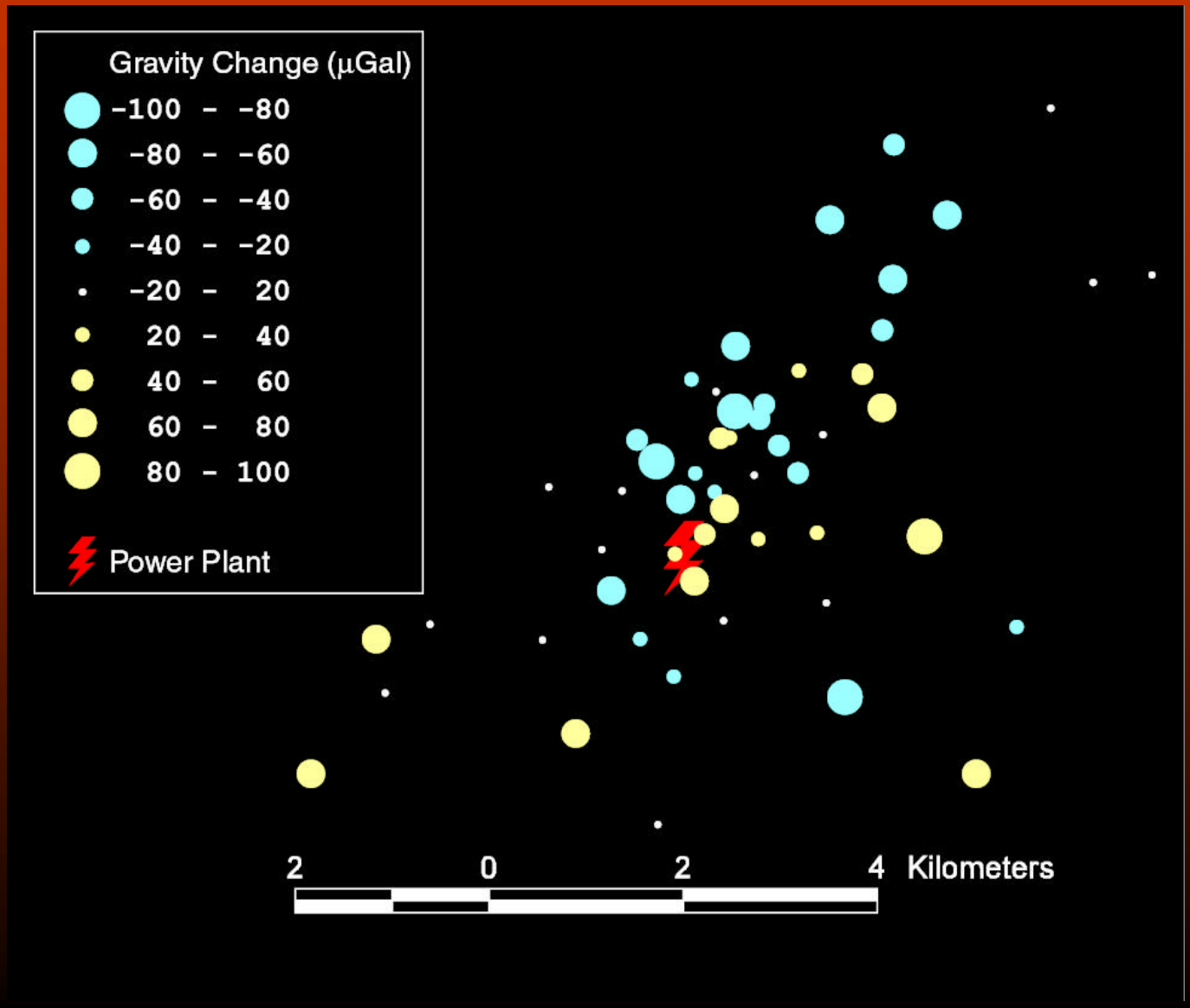
Jun 1999 to Oct 1999



Elevation Change
Oct 1999 to Jun 2000

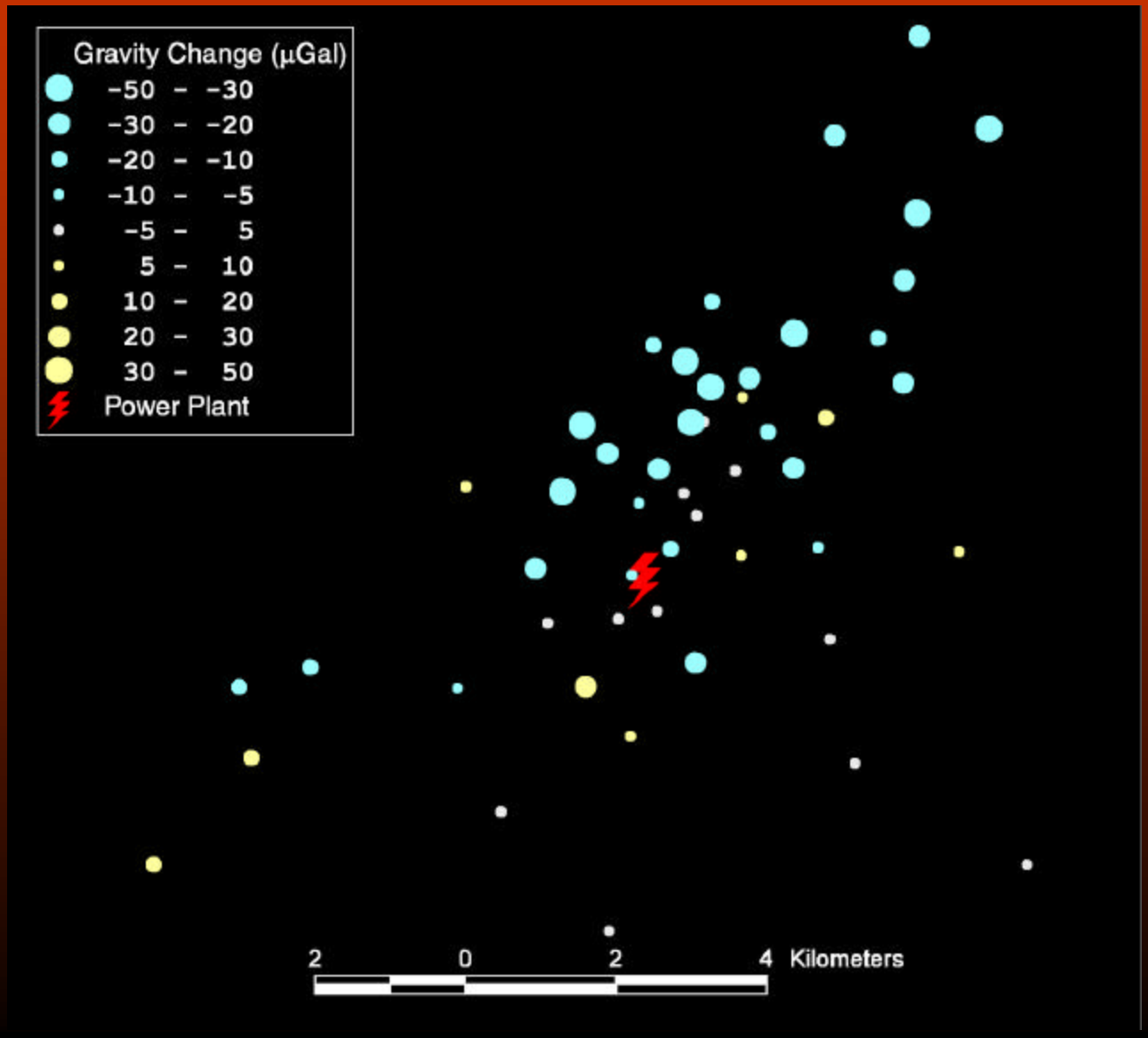


Free-air Corrected Gravity Change
Oct 1999 to Jun 2000



Uncorrected Gravity Change

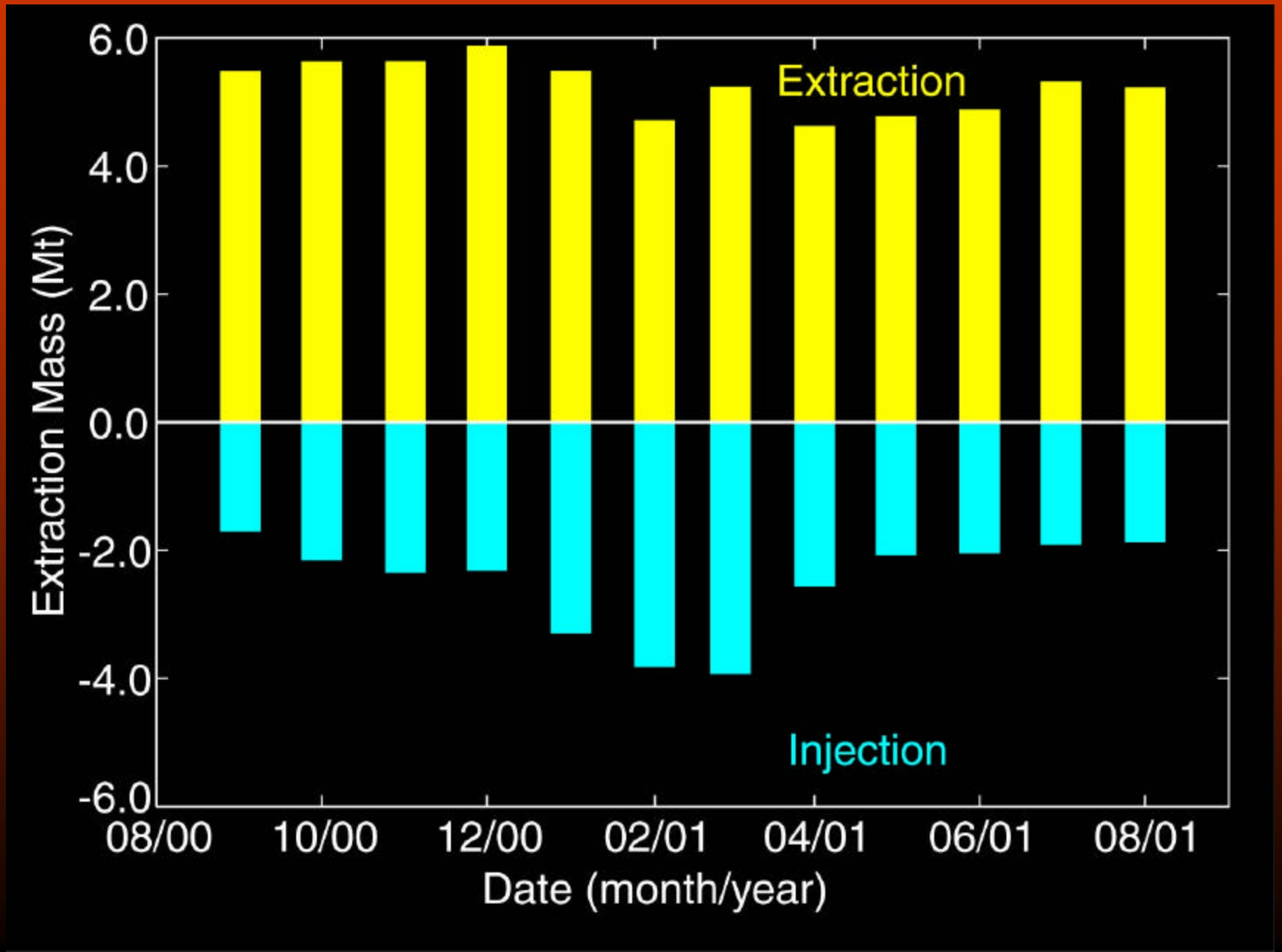
Oct 1999 to Jun 2000



Gravity Data Analysis

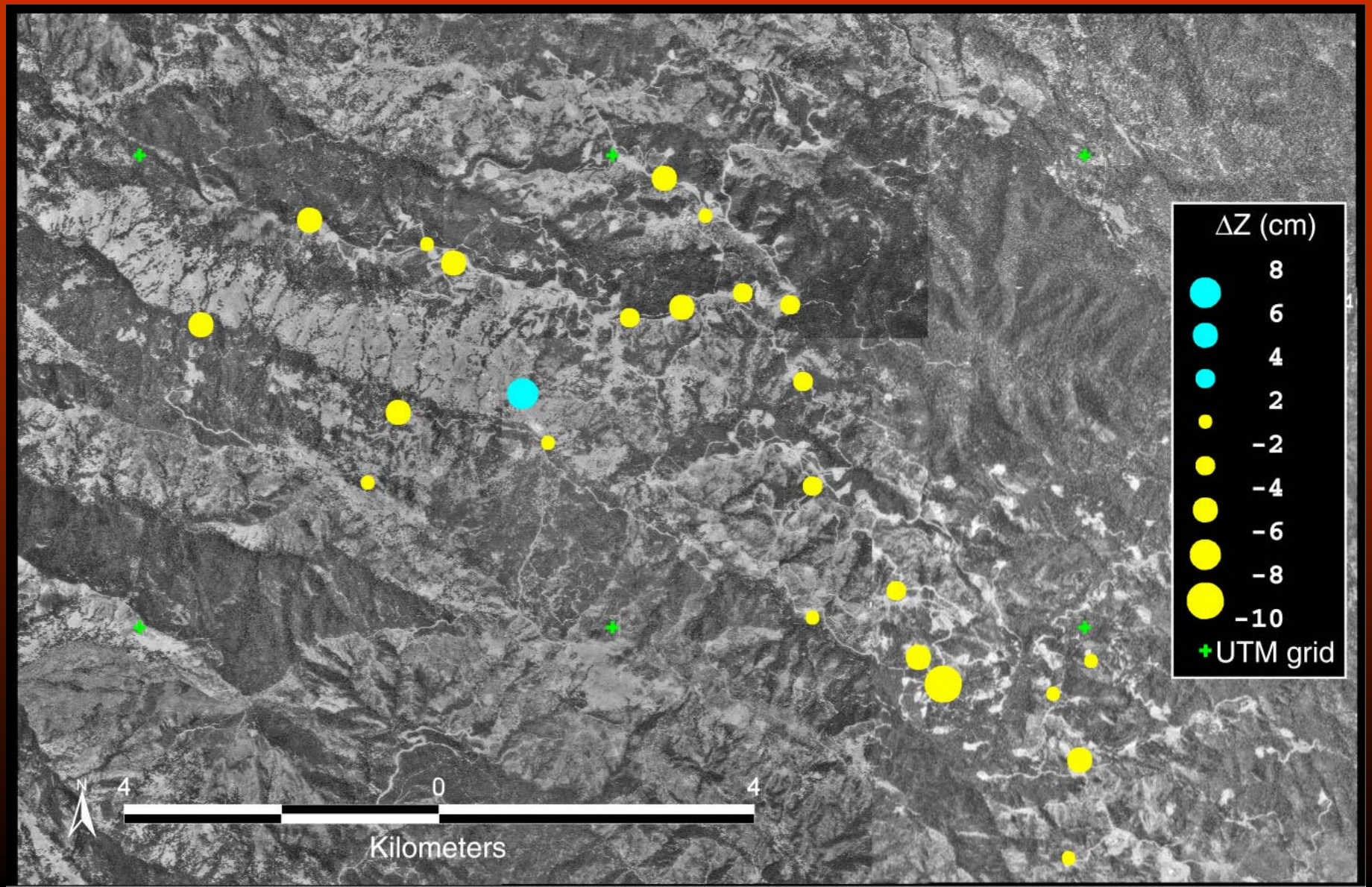
- Analysis of the gravity changes requires knowledge of both the production and ground water history of the field
- For Dixie Valley, production data have not yet been incorporated in the analysis.
- Such data have been used for our most recent work at The Geysers, CA

The Geysers Production History



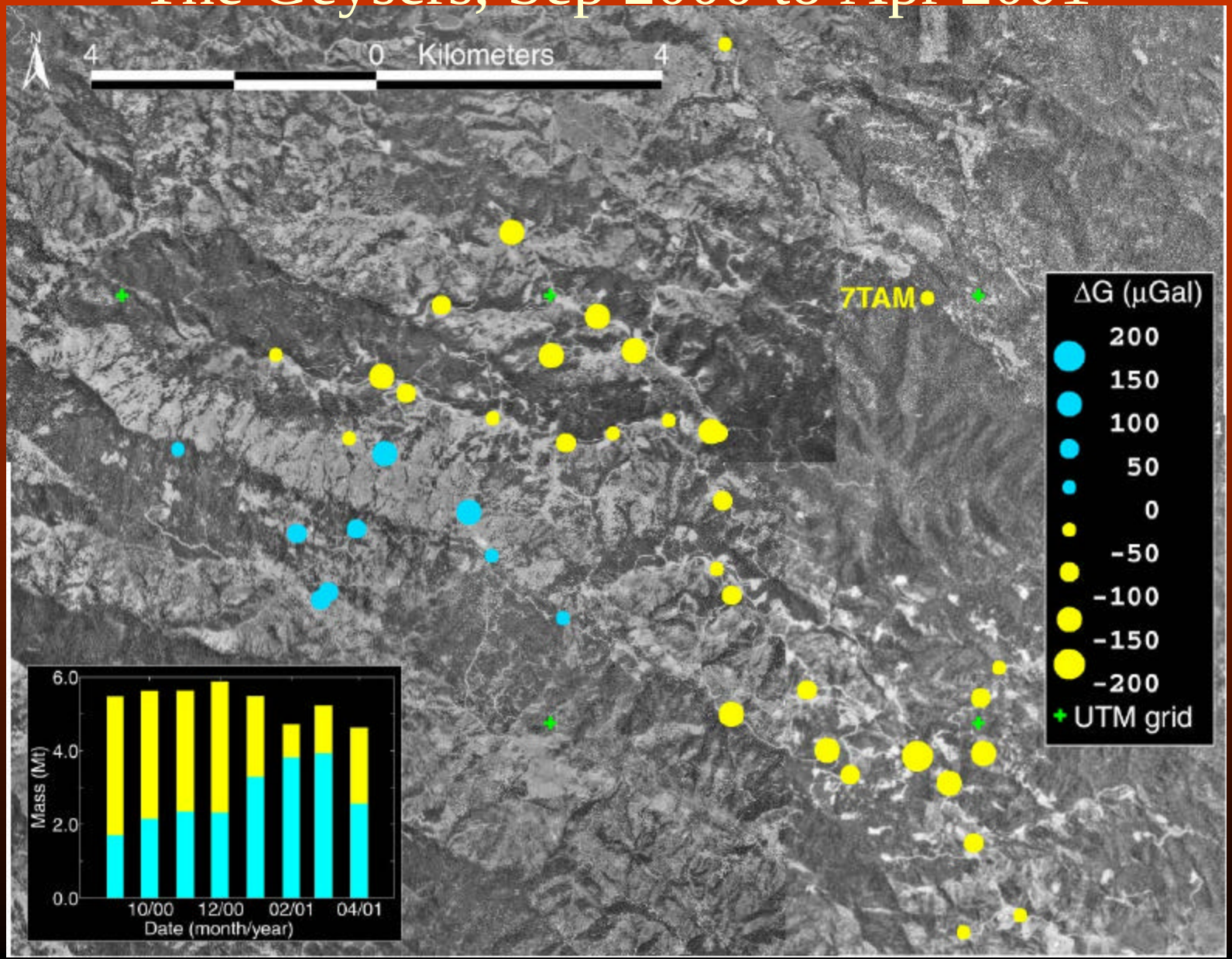
Elevation Change

The Geysers, Sep 2000 to Apr 2001



Gravity Change

The Geysers, Sep 2000 to Apr 2001



Predicted Gravity Effects

The Geysers, Sep '00 to Apr '01

- 1-D Bouguer Slab: $\Delta G = 40\ \Delta M / A$
  - Assume $A = 40\ km^2$, ΔM in Mt, ΔG in μGal
- Net mass loss of 20.55 Mt → -20 μGal
- Max/min mass changes:
  - 42.68 Mt loss → -43 μGal signal
  - 22.13 Mt gain → +22 μGal signal
- Ground water change
  - Estimate $\Delta Z = 1.8m$ → +15 μGal
  - Assume Φ=20%
- Observed average ΔG = -38 μGal

Conclusions

- Repeated gravity & GPS measurements have been performed at Dixie Valley.
- Elevation differences are large, with very short wavelength changes; possibly a systematic processing error.
- Uncorrected gravity differences show larger changes (>20 μGal) near production wells, less change near injection wells, and no significant change towards the center of the valley

Future Work

- Compare GPS data against InSAR, etc. to resolve the source of the apparent large changes
- Correlate gravity & GPS changes with production history
- Continue monitoring to improve understanding of the reservoir

Acknowledgements

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